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Transmitted herewith for filing is the patent application of

Inventor(s): **Tetsuya Mashiko and Takeshi Hirasawa**For: **MULTIPLE VALVE ENGINE FOR WATERCRAFT**

Enclosed are:

- (X) Specification in SEVENTEEN (17) pages.
- (X) SIX (6) sheets of drawings.
- (X) Certified copy of Japanese Application No. 11-277919, filed September 30, 1999.
- (X) Information Disclosure Statement, Form PTO 1449 and 4 references.
- (X) Return prepaid postcard.

CLAIMS AS FILED

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Applicant(s) : Tetsuya Mashiko et al.

For : MULTIPLE VALVE ENGINE FOR
WATERCRAFT

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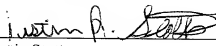
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MULTIPLE VALVE ENGINE FOR WATERCRAFTPRIORITY INFORMATION

- 5 This invention is based on and claims priority to Japanese Patent Applications No. Hei 11-277919, filed September 30, 1999, the entire contents of which is hereby expressly incorporated by reference.

BACKGROUND OF THE INVENTIONField of the Invention

- 10 This invention relates to a multiple valve engine for a watercraft, and more particularly to an engine for a watercraft that has intake and exhaust valves which are different in number.

Description of Related Art

- 15 Personal watercraft have become very popular in recent years. This type of watercraft is quite sporting in nature and carries one or more riders. A relatively small hull of the personal watercraft commonly defines a rider's area above an engine compartment. An internal combustion engine powers a jet propulsion unit which propels the watercraft. The engine lies within the engine compartment in front of a tunnel formed on an underside of the hull. The jet propulsion unit, which includes an impeller, is placed within the tunnel.
- 20 The impeller has an impeller shaft driven by the engine. The impeller shaft usually extends between the engine and the jet propulsion device through a bulkhead of the hull tunnel.

- 25 Because the riders straddle a longitudinally extending seat, which is placed in the rider's area above the engine, the engine is required to be as short as possible in height. Some prior engines therefore have been slanted toward one side of the hull to reduce the height of the engine.

- 30 Personal watercrafts with a four-cycle engine are now being designed to reduce exhaust emissions. The four-cycle engine, however, normally has multiple valves and a valve drive mechanism arranged to actuate the valves. The valves and valve drive mechanism are generally made of metal material that is heavier than other materials. If the engine is slanted as noted above, the hull side to which the engine is slanted bears more weight than the other side. This imbalance in weight affects the handling characteristics of the watercraft.

A need therefore exists for an improved multiple valve engine that can aid in balancing the weight of engine with the hull.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, an internal combustion engine is provided for a watercraft that has a hull defining a center plane extending generally vertically from bow to stern. The engine comprises a cylinder body defining at least one cylinder bore. An axis of the cylinder bore is inclined relative to the center plane. A piston reciprocates within the cylinder bore. A cylinder head member closes an end of the cylinder bore and defines a combustion chamber with the cylinder bore and the piston. The cylinder head has a first set of passages that comprises at least two passages which communicate with the combustion chamber. A first set of valves is arranged to selectively connect and disconnect the passages of the first set of passages with the combustion chamber. The cylinder head also has a second set of passages comprising at least one passage that communicates with the combustion chamber. The second set of passages is less in number than the first set of passages. A second set of valves is arranged to selectively connect and disconnect the second set of passages with the combustion chamber. The first set of valves lies closer to the center plane than does the second set of valves.

In accordance with another aspect of the present invention, an internal combustion engine is provided for a watercraft having a hull defining a center plane extending generally vertically from bow to stern. The engine comprises a cylinder body mounted on the hull. The cylinder body defines at least one cylinder bore. A piston reciprocates within the cylinder bore. A cylinder head member closes an end of the cylinder bore and defines a combustion chamber with the cylinder bore and the piston. The cylinder head member is inclined toward one side of the hull from the center plane. A plurality of air intake passages introduce air to the combustion chamber. At least one exhaust passage receives exhaust gases from the combustion chamber. The air intake passages are greater in number than the at least one exhaust passage. Air intake valves are arranged to selectively open and close the air intake passages. At least one exhaust valve is arranged to open and close the at least one exhaust passage. An intake camshaft is arranged to actuate the intake valves. An exhaust camshaft is arranged to actuate the at least one exhaust valve. Both the intake and exhaust camshafts extend generally in

parallel to the center plane. The intake camshaft lies closer to the center plane than does the exhaust camshaft.

Further aspects, features and advantages of this invention will become apparent from the detailed description of the preferred embodiment which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of this invention will now be described with reference to the drawings of a preferred embodiment which is intended to illustrate and not to limit the invention. The drawings contain the following figures.

FIGURE 1 is a side elevational view of a personal watercraft of the type powered by an engine configured in accordance with a preferred embodiment of the present invention.

FIGURE 2 is a top plan view of the watercraft.

FIGURE 3 is a schematic, cross-sectional front view of the watercraft and the engine taken along the line 3-3 of FIGURE 2. A profile of a hull of the watercraft is shown schematically except for an opening of an engine compartment. A seat is illustrated in phantom. In this figure, the right-hand side is the port side of the watercraft, while the left-hand side is the starboard side thereof.

FIGURE 4 is an enlarged, top plan view of the engine. A cylinder head cover member and cam chamber housings are removed. A plenum chamber and an air cleaner element are shown in phantom.

FIGURE 5 is a schematic top plan view of the plenum chamber. A plenum chamber member is shown in section taken along the line 5-5 of FIGURE 3.

FIGURE 6 is a schematic, cross-sectional view of the watercraft and an additional engine configuration. The watercraft and the engine are illustrated in a manner similar to FIGURE 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

With reference to FIGURES 1 to 5, a personal watercraft 30 employs an internal combustion engine 32 configured in accordance with a preferred embodiment of the present invention. The engine configuration has particular utility with the personal watercraft, and thus, is described in the context of the personal watercraft. The engine configuration, however, can be applied to other types of watercrafts as well, such as, for example, small jet boats.

With initial reference to FIGURES 1 to 3, the personal watercraft 30 includes a hull 34 generally formed with a lower hull section 36 and an upper hull section or deck 38. Both the hull sections 36, 38 are made of, for example, a molded fiberglass reinforced resin or a sheet molding compound. The lower hull section 36 and the upper hull section 38 are coupled together to define an internal cavity 40. A gunnel 42 defines an intersection of both the hull sections 36, 38.

As seen in FIGURES 2 and 3, the hull 34 defines a center plane CP that extends generally vertically from bow to stern. Along the center plane CP, the upper hull section 34 includes a hatch cover 48, a control mast 50 and a seat 52 one after another from fore to aft.

In the illustrated embodiment, a bow portion 53 of the upper hull section 38 slopes upwardly and an opening is provided through which the rider can access the internal cavity 40. The hatch cover 48 is detachably affixed (e.g., hinged) to the bow portion 53 so as to cover the opening.

The control mast 50 extends generally upwardly almost atop the bow portion 53 to support a handle bar 54. The handle bar 54 is primarily provided for controlling the directions in which the water jet propels the watercraft 30. The handle bar 54 also carries other control units such as, for example, a throttle lever 56 that is used for control of running conditions of the engine 32.

The seat 52 extends along the center plane CP in the rear of the bow portion 53. This area in which the seat 52 is positioned is a rider's area. The seat 52 has a saddle shape and hence the rider can straddle it. Foot areas 60 are defined on both sides of the seat 52 and at the top surface of the upper hull section 38. The foot areas 60 are formed generally flat. A cushion supported by the upper hull section 38, at least in principal part, forms the seat 52. The seat 52 is detachably attached to the upper hull section 38. An access opening 62 is defined under the seat 52 through which the rider can also access the internal cavity 40. That is, the seat 52 usually closes the access opening 62. In the illustrated embodiment, the upper hull section 38 also defines a storage box 64 under the seat 52.

A fuel tank 66 is placed in the cavity 40 under the bow portion 53 of the upper hull section 38. The fuel tank 66 is coupled with a fuel inlet port positioned at a top surface of the upper hull section 38 through a duct. A closure cap 68 closes the fuel inlet port. The opening disposed under the hatch cover 48 is available for accessing the fuel tank 66.

The engine 32 is placed in an engine compartment defined in the cavity 40. The engine compartment preferably is located under the seat 52, but other locations are also

possible (e.g., beneath the control mast or in the bow). The rider thus can access the engine 32 in the illustrated embodiment through the access opening 62 by detaching the seat 52. At least one air duct is provided at the bow portion 53 so that the ambient air can enter the internal cavity 40 therethrough. Except for the air duct(s), the engine compartment is substantially sealed so as to protect the engine 32 and a fuel supply system, including the fuel supply tank 66, from water.

A jet pump unit 72 propels the watercraft 30. The jet pump unit 72 includes a tunnel 74 formed on the underside of the lower hull section 36 which is isolated from the engine compartment by a bulkhead. The tunnel has a downward facing inlet port 75 opening toward the body of water. A jet pump housing 76 is disposed within a portion of the tunnel 74 and communicates with the inlet port 75. An impeller is supported with the housing 76. An impeller shaft 78 extends forwardly from the impeller and is coupled with a crankshaft 80 of the engine 32 by a coupling member 82. The crankshaft 80 of the engine 32 thus drives the impeller shaft 78. The rear end of the housing 76 defines a discharge nozzle and a steering nozzle 84 is affixed to the discharge nozzle for pivotal movement about a steering axis extending generally vertically. The steering nozzle 84 is connected to the handle bar 54 by a cable so that the rider can steer the nozzle 84.

When the engine 32 drives the impeller shaft 78 and hence the impeller rotates, water is drawn from the surrounding body of water through the inlet port 75. The pressure generated in the housing 76 by the impeller produces a jet of water that is discharged through the steering nozzle 84. This water jet propels the watercraft 30. The rider can move the steering nozzle 84 with the handle bar 54 when he or she desires to turn the watercraft 30 in either direction.

Still with reference to FIGURES 1 to 3 and additionally with reference to FIGURES 4 and 5, the engine 32 will now be described in great detail. The engine 32 operates on a four-stroke cycle combustion principle. The engine 32 includes a cylinder block 90. Engine mounts 92 extend from both sides of the cylinder block 90 and have elastic members 94 made of, for example, rubber material at end portions thereof. The engine 32 is mounted on the lower hull section 36 through the engine mounts 92 via the elastic members 94.

The cylinder block 90 defines four cylinder bores 98 spaced apart from each other from fore to aft along the center plane CP. The cylinder block 90 defines four cylinder bores 98 spaced apart from each other from fore to aft along the center plane CP. The

engine 32 thus is a L4 (in-line four cylinder) type. The illustrated engine, however, merely exemplifies one type of engine on which various aspects and features of the present invention can be used. Engines having other number of cylinders and operating on other combustion principles (e.g., crankcase compression two-stroke) are all practicable.

5 Each cylinder bores 98 has a center axis CA that is slanted or inclined at a certain angle from the center plane CP so that the engine 32 can be short in height. All the center axes CA in the illustrated embodiment have the same angle. Pistons 100 reciprocate within the cylinder bores 98. A cylinder head member 102 is affixed to the upper end of the cylinder block 90 to close respective upper ends of the cylinder bores 98 and defines
10 combustion chambers 104 with cylinder bores 98 and the pistons 100.

A crankcase member 105 is affixed to the lower end of the cylinder block 90 to close the respective lower ends of the cylinder bores 98 and to define a crankcase chamber 106 with the cylinder block 90. The crankshaft 80 is rotatably connected to the pistons 100 through connecting rods 108 and journaled by the crankcase member 105. That is, the
15 connecting rods 108 are rotatably coupled with the pistons 100 by piston pins 110 and with the crankshaft 80. The crankshaft 80 rotates with the reciprocal movement of the pistons 100 between a top dead center position and a bottom dead center position. In the illustrated embodiment, axes of the respective piston pins 110 exist on and extend along the center plane CP when the pistons 100 are at the top dead center. Also, an axis of the crankshaft 80
20 is offset from the center plane CP. This is because a reduction gear is interposed between the crankshaft 80 and the impeller shaft 78.

The cylinder block 90, the cylinder head member 102 and the crankcase member 105 together define an engine body. In the illustrated embodiment, the engine body is oriented in the engine compartment so as to position the crankshaft 80 generally parallel to
25 the central plane CP and to extend generally in the longitudinal direction. Other orientations of the engine body, of course, are also possible (e.g., with a transverse or vertical oriented crankshaft).

The engine 32 includes an air induction system to introduce air to the combustion chambers 104. In the illustrated embodiment, the air induction system includes four air
30 intake passages 116 defined in the cylinder head member 102. The respective intake passages 116 are branched off to three intake paths that are allotted to each combustion chamber 104. The engine 32 thus includes twelve intake paths in total. The intake passages 116 communicate with the associated combustion chambers 104. Intake valves 117, which

are the same as the intake paths in number, i.e., twelve valves 117, are provided to selectively connect and disconnect the branch paths with the combustion chambers 104. In other words, the intake valves 117 selectively open and close the branch paths of the intake passages 116.

5 The air induction system also includes a plenum chamber or air intake chamber 118. The plenum chamber 118 in the illustrated embodiment is generally configured as a rectangular and is defined by a plenum chamber member 120. Other shapes of the plenum chamber of course are also possible, but it is desired to made the plenum chamber as large as possible within the space provided in the engine compartment. In the illustrated
10 embodiment, a layer of space exists between the top of the engine and the bottom of the seat due to the inclined orientation of the engine. The rectangular box-like shape of a principal portion of the plenum chamber member achieves these design parameters in the illustrated embodiment.

The plenum chamber member 120 comprises an upper chamber member 120a and a
15 lower chamber member 120b coupled together in a suitable manner. The upper and lower members are made of plastic, although they can be made of metal material. While the illustrated embodiment involves the chamber member being formed by upper and lower chamber members, the chamber member can be formed by a different number of members and/or could have a different assembly orientation (e.g., side-by-side).

20 The lower chamber member 120b is coupled with the cylinder head member 102 so that the intake passages 116 communicate with the plenum chamber 118. The plenum chamber 118 extends from one side surface of the cylinder head member 102 toward a space defined between the cylinder head member 102 and the seat 52, i.e., the rider's area of the hull 34, so as to ensure a relatively large volume therein.

25 As seen in FIGURES 3 and 5, a pair of air inlet ports 122, each has a duct shape, is defined at a bottom portion of the lower chamber member 120b positioned right above the cylinder head member 116. The inlet ports 122 project into the plenum chamber 118. An air cleaner element 124 is disposed within the plenum chamber so as to surround the air inlet ports 120. The air cleaner element 124 divides the plenum chamber 118 into two
30 spaces which are an inner space and an outer space of the element 124. The air inlet ports 122 are positioned in the inner space. The air in the internal cavity 40 of the hull 34 is thus introduced into the plenum chamber 118 and is sure to pass through the cleaner element 124 before moving downstream of the plenum chamber 118.

The air induction system further includes throttle bodies 128 each associated with each one of the combustion chambers 104. In the illustrated embodiment again, the throttle bodies 128 are placed within the plenum chamber 118, more specifically, in the space between the exterior of the cleaner element 124 and the walls of the plenum chamber, and spaced apart from each other along a direction that is parallel to the center plane CP. The throttle bodies 128 project into the plenum chamber 118 so as to lie next to the air inlet ports 122 with a portion of the air cleaner lying therebetween.

As seen in FIGURE 3, the air intake passages 116 slant oppositely relative to the center axes CA of the cylinder bores 98. Because they extend along the same axes of the intake passages 116, the throttle bodies 128 also slant oppositely relative to the center axes CA of the cylinder bores 98.

The respective throttle bodies 128 have air suction ports 130, which are shaped as bell mouths, opening upwardly. Throttle valves are provided in the respective throttle bodies 128 and are linked together by a suitable throttle linkage so as to move in unison. The throttle linkage is connected to the throttle lever 56 on the handle bar 54 through a cable. The rider thus can control openings of the throttle valves by operating the throttle lever 56 so as to obtain various running conditions of the engine 32 that he or she desires. That is, an amount of the air is measured by this mechanism and delivered to the respective combustion chambers 104.

Each throttle body 128 has an end flange 129 and is affixed to the cylinder head member 102 at the end flange 129. The lower chamber member 120b has a portion that defines an opening, through which the throttle body 128 communicates with the intake passage 116, and this portion of the lower chamber member 120b is interposed between the end flange 129 of the throttle body 128 and the cylinder head member 102 so as to be affixed to the cylinder head member 102. Other portions of the lower chamber member 120b are also affixed to the cylinder head member 102 in a suitable manner, although those portions are not seen.

The engine 32 also includes a fuel supply system. The fuel supply system includes the foregoing fuel supply tank 66 and fuel injectors 132 that are affixed to a fuel rail 134 and are mounted on the throttle bodies 128. The fuel rail 134 extends generally horizontally in the longitudinal direction in the illustrated embodiment. Because the throttle bodies 128 are disposed within the plenum chamber 118, the fuel injectors 132 are inevitably

positioned within the plenum chamber 118. Each fuel injector 132 has an injection nozzle directed toward the intake passage 116 associated with each fuel injector 132.

The fuel supply system includes a low-pressure fuel pump, a vapor separator, a high-pressure fuel pump and a pressure regulator, in addition to the fuel supply tank 66, the fuel injectors 132 and the fuel rail 134. Fuel supplied from the fuel supply tank 66 in the hull 34 is pressurized by the low pressure fuel pump and is delivered to the vapor separator in which the fuel is separated from fuel vapors. One or more high pressure fuel pumps draw the fuel from the vapor separator and pressurize the fuel before it is delivered to the fuel rail. The pressure regulator controls the pressure of the supplied fuel and limits the fuel pressure to a preset pressure level. The fuel rail 134 not only supports the fuel injectors 132 but also delivers the fuel to the respective fuel injectors 132. The fuel injectors 132 spray the fuel into the intake passages 116 at certain injection timings and for certain duration under control of an ECU (Electronic Control Unit).

The sprayed fuel is delivered to the combustion chambers 104 with the air when the intake passages 116 are opened to the combustion chambers 104 by the intake valves 117. The air and the fuel are mixed together in the combustion chambers 104 to form air/fuel charges. Four spark plugs 136 (FIGURE 4) are affixed to the cylinder head member 102 so that electrodes of the plugs 136 are exposed to the respective combustion chambers 104. The spark plugs 136 are fired at certain ignition timings under control of the ECU. The air/fuel charge is thus burned during every combustion stroke.

In the illustrated embodiment, as described above, the throttle bodies 128 and the fuel injectors 132 are disposed within the plenum chamber 118. This is advantageous because the plenum chamber 118 can have a larger capacity in comparison with a situation in which the plenum chamber member 120 does not enclose the throttle bodies 128 and the fuel injectors 132. Consequently, the position of the seat 52 can remain the same without reducing the desired volume with the plenum chamber and with the inclusion of the larger four-cycle engine in the engine compartment.

In addition, the throttle bodies 128, throttle valves and the fuel injectors 132 are well protected from any water within the engine compartment that may splash onto the plenum chamber member or that may enter the engine compartment when the seat 52 is detached. It is particularly advantageous to isolate these components from water, especially salt water, because these components involve sensitive mechanical and electrical parts that have precise operation and that are likely to be damaged by rust and/or corrosion.

5 The engine 32 has an exhaust system to discharge burnt charges, i.e., exhaust gases, in the combustion chambers 104. In the illustrated embodiment, the exhaust system includes four exhaust passages 138 and the respective exhaust passages 138 are branched off to two exhaust paths that are allotted to each combustion chamber 104. The engine 32 thus includes eight exhaust paths in total. The exhaust passages 138 are defined in the cylinder head member 102 and communicate with the associated combustion chambers 104. Exhaust valves 140, which are the same as the exhaust paths in number, i.e., eight valves 140, are provided to selectively connect and disconnect the branch paths with the combustion chambers 104. In other words, the exhaust valves 140 selectively open and close the branch paths of the exhaust passages 138.

10 An exhaust manifold 144 is coupled with the exhaust passages 138. In the illustrated embodiment, the exhaust manifold 144 has four unified paths communicating with the respective exhaust passages 138 to gather exhaust gases from the passages 138. The exhaust manifold 144 defines a first exhaust passageway 146 including the unified paths. The exhaust manifold 144 extends forwardly and terminates at a forward facing end.

15 An exhaust conduit or header pipe 148 is coupled with the end 146 of the exhaust manifold 144 and defines a second exhaust passageway. As best seen in FIGURE 4, the header pipe 148 extends generally transversely across the center plane CP to the opposite side of the engine 32. The header pipe 148 has an end opening directed rearwardly.

20 An exhaust silencer 152 is coupled with the rearward opening of the header pipe 148 and defines a third exhaust passageway 154. The exhaust silencer 152 extends rearwardly along the opposite side surface of the cylinder block 90 relative to the exhaust manifold 144. The exhaust silencer 152 also defines an inner structure such as, for example, an expansion chamber, to reduce exhaust noises passing therethrough. As seen in FIGURE 25 3, the header pipe 148 extends upwardly toward the exhaust silencer 152 because the exhaust silencer 152 is positioned higher than the exhaust manifold 144.

30 As seen in FIGURE 2, a water-lock 156 is coupled with the exhaust silencer 152 by a coupling pipe 158, and an exhaust conduit 160 is further coupled with the water-lock 156. The exhaust conduit 160 has a discharge opening 162 located at a submerged portion of the lower hull section 36. The discharge opening 162 is positioned at the end of the exhaust conduit 160 on the same side as the exhaust manifold 144. The exhaust conduit 160 extends forwardly from the discharge opening 162 and then transversely across the center plane CP and connected to the water-lock 156. The water-lock 156 inhibits the water in the

exhaust conduit 160 from entering the exhaust pipe 152. Because the water-lock 156 has a relatively large capacity, it may function as an expansion chamber also.

FIGURE 6 illustrates another arrangement of the exhaust pipe 148 and the exhaust silencer 152. The exhaust pipe 148 in this arrangement extends upwardly and then the exhaust silencer 152 is coupled with the exhaust pipe 148. Both the exhaust pipe 148 and the exhaust silencer 152 are thus positioned on the same side of the exhaust manifold 144. Constructions other than this arrangement of the exhaust pipe 148 and the exhaust silencer 152 are the same as those shown in FIGURES 1 to 5.

The engine 32 has a water cooling system. The cooling system includes a water pump arranged to introduce water from the body of water surrounding the watercraft 30, and a plurality of water jackets defined, for example, in the cylinder block 90 and the cylinder head member 102. The jet propulsion unit preferably is used as the water pump with a portion of the water pressurized by the impeller being drawn off for the cooling system, as known in the art. Although the water is primarily used for cooling these engine portions, part of the water is used also for cooling the exhaust manifold 144, exhaust pipe 148 and the exhaust silencer 152. The exhaust components 144, 148, 152 are therefore formed as dual passage structures. More specifically, water jackets 166 are defined around the respective exhaust passageways 146, 154.

Still with reference to FIGURES 3 and 4, a valve drive mechanism will be described. In the illustrated embodiment, double overhead camshafts drive the intake and exhaust valves 117, 140. That is, the intake valves 117 are driven by an intake camshaft 170 that extends generally horizontally over the intake valves 117 from fore to aft in parallel to the center plane CP, while the exhaust valve 140 are driven by an exhaust camshaft 172 that extends generally horizontally over the exhaust valves 140 from fore to aft also in parallel to the center plane CP. Both the intake and exhaust camshafts 170, 172 are journaled by the cylinder head member 102 with a plurality of camshaft caps 174. The camshaft caps 174 holding the camshafts 170, 172 are affixed to the cylinder head member 102 by bolts 176. A camshaft cover 178 extends over the camshafts 170, 172 and the camshaft caps 174, and is affixed to the cylinder head member 102 to define camshaft chambers. Additionally, a cylinder head cover 180 extends over the camshaft cover 178 and is affixed to the cylinder head member 102.

The intake camshaft 170 has twelve cam lobes 184 each associated with each one of the intake valves 117, while the exhaust camshaft 172 has eight cam lobes 186 each

associated with each one of the exhaust valve 140. The intake and exhaust valves 117, 140 normally close the intake and exhaust passages 116, 138 by biasing force of springs. When the intake and exhaust camshafts 170, 172 rotate, the cam lobes 184, 186 push the respective valves 117, 140 to open the respective passages 116, 138 by overcoming the biasing force. The air thus can enter the combustion chambers 104 at every opening timing of the intake valves 117. In the same manner, the exhaust gases can move out from the combustion chambers 104 at every opening timing of the exhaust valves 140.

The crankshaft 80 drives the intake and exhaust camshafts 170, 172. As seen in FIGURE 4, the respective camshafts 170, 172 have driven sprockets 190 affixed to ends thereof. The crankshaft 80 also has a drive sprocket. The driven sprockets 190 have diameters which are twice as large as a diameter of the drive sprocket. A timing chain or belt is wound around the drive and driven sprockets 190. When the crankshaft 80 rotates, the drive sprocket drives the driven sprockets 190 via the timing chain, and then the intake and exhaust camshafts 170, 172 rotate also. The rotational speed of the camshafts 170, 172 are reduced to half as the rotational speed of the crankshaft 80 because of the differences in diameters of the drive and driven sprockets 190.

Ambient air enters the internal cavity 40 defined in the hull 34 through the air ducts. The air is then introduced into the plenum chamber 118 through the air inlet ports 123 and moves to the throttle bodies 128. The air cleaner element 124 cleans the air. The throttle valves in the throttle bodies 128 regulate an amount of the air permitted to pass to the combustion chambers. Changing the opening angles of the throttle valves that are controlled by the rider with the throttle lever 56 regulates the air flow across the valves. The air hence flows into the combustion chambers 104 when the intake valves open. At the same time, the fuel injectors 132 spray fuel into the intake passages 116 under the control of ECU. Air/fuel charges are thus formed and delivered to the combustion chambers 104.

The air/fuel charges are fired by the spark plugs 136 under the control of the ECU. The burnt charges, i.e., exhaust gases, are discharged to the body of water surrounding the watercraft 30 through the exhaust system including the exhaust passages 138, exhaust manifold 144, exhaust pipe 148, exhaust silencer 152, water-lock 158 and exhaust conduit 160.

The combustion of the air/fuel charges has the pistons 100 reciprocate to rotate the crankshaft 80. The crankshaft 80 drives the impeller shaft 78 and the impeller rotates in the hull tunnel 74. Water is thus drawn into the tunnel 74 through the inlet port 76 and then is

discharged rearward through the steering nozzle 84. The rider can steer the nozzle 84 by the steering handle bar 54. The watercraft 30 thus moves as the rider desires.

As best seen in FIGURE 3, in the illustrated embodiment, all the valves 117, 140 and the camshafts 170, 172 are positioned in one half space of the hull 30 divided by the center plane CP. More specifically, the internal cavity 40 defined by both the upper and lower hull sections 36, 38 is divided by the center plane CP into two cavity spaces. The valves 117, 140 and the camshafts 170, 172 are placed in one of these spaces. The group of the intake valves 117 and the intake camshaft 170, which are heavier than the other group of the exhaust valves 140 and the exhaust camshaft 172, exist closer to the center plane CP.

In other variations, for example, the intake valves 117 can be disposed in the other space wholly or partially. The intake camshafts 170 can be also positioned in the other space, if top portions of the intake valves 117 exist in the cavity space. In this variation, the heavier group exists in the other space but closer to the center plane CP than the other group. The moment of the heavier group thus can balance the moment of the lighter group relative to the center plane CP. This arrangement thus can contribute in balancing the weights of both sides of the hull.

Also, if the exhaust valves 140 are greater than the intake valves 117 in number, the positions of the exhaust valves 140 are changeable with the intake valves 117. In any instance, however, if the center axis CA of the cylinder bores 98 is inclined relative to the center plane CP, the valves, which are greater in number than the other valves, lie closer to the center plane CP.

Of course, the foregoing description is that of a preferred embodiment of the present invention, and various changes and modifications may be made without departing from the spirit and scope of the invention, as defined by the appended claims.

WHAT IS CLAIMED IS:

1. An internal combustion engine for a watercraft having a hull defining a center plane extending generally vertically from bow to stern, comprising a cylinder body defining at least one cylinder bore, an axis of the cylinder bore slanting from the center plane, a piston reciprocating within the cylinder bore, a cylinder head member closing an end of the cylinder bore and defining a combustion chamber with the cylinder bore and the piston, a first set of passages having at least two passages communicating with the combustion chamber, a first set of valves arranged to selectively connect and disconnect the first set of passages with the combustion chamber, a second set of passages having at least one second passage communicating with the combustion chamber, the second set of passages being fewer in number than the first set of passages, and a second set of valves comprising at least one valve arranged to selectively connect and disconnect the at least one passage of the second set of passages with the combustion chamber, the first set of valves being disposed closer to the center plane than the second set of valves.

2. The internal combustion engine as set forth in Claim 1, wherein both the first and second set of valves exist on the same side of the center plane within the hull.

3. The internal combustion engine as set forth in Claim 1 additionally comprising a crankshaft, a connecting rod rotatably connecting the crankshaft with the piston, the piston having an axis at which the connecting rod is rotatably coupled with the piston, and the axis generally extending within the center plane during at least one point of reciprocal travel of the piston within the cylinder bore.

4. The internal combustion engine as set forth in Claim 3, wherein the piston reciprocates between the top dead center and the bottom dead center, and the axis generally exists on the center plane when the piston is at the top dead center.

5. The internal combustion engine as set forth in Claim 1, wherein the second set of valves includes at least two valves.

6. The internal combustion engine as set forth in Claim 5, wherein the first set of valves has three valves and the second set of valves has two valves.

7. The internal combustion engine as set forth in Claim 1, wherein the passages of the first set of passages are arranged to introduce the air to the combustion chamber and the at least one passage of the second set of passages is arranged to receive the exhaust gases from the combustion chamber.

8. The internal combustion engine as set forth in Claim 1 additionally comprising at least one camshaft arranged to actuate at least some of the valves, and the camshaft extending generally in parallel to the center plane.

9. The internal combustion engine as set forth in Claim 8, wherein the engine includes a first camshaft and a second camshaft, the first camshaft actuates the first set of valves, the second camshaft actuates the at least one valve of the second set of valves, and the first camshaft lies closer to the center plane than does the second camshaft.

10. The internal combustion engine as set forth in Claim 8, wherein the camshaft has cam lobes configured to push the first and second valves.

11. The internal combustion engine as set forth in Claim 1, wherein at least one of the passages of the first set of passages extends across the center plane.

12. The internal combustion engine as set forth in Claim 11, wherein the passages of the first set of passages are arranged to introduce the air into the combustion chamber.

13. The internal combustion engine as set forth in Claim 1, wherein the cylinder bore extends across the center plane.

14. The internal combustion engine as set forth in Claim 1, wherein the engine includes at least two cylinder bores, and the cylinder bores are spaced apart from each other along the center plane.

15. The internal combustion engine as set forth in Claim 1 additionally including an ignition control system that operates on a four-stroke cycle combustion principle.

16. An internal combustion engine for a watercraft having a hull defining a center plane extending generally vertically from bow to stern, comprising a cylinder body mounted within the hull, the cylinder body defining at least one cylinder bore, a piston reciprocating within the cylinder bore, a cylinder head member closing an end of the cylinder bore and defining a combustion chamber with the cylinder bore and the piston, the cylinder head member slanting toward one side of the hull from the center plane, a plurality of air intake passages introducing air to the combustion chamber, and at least one exhaust passage receiving exhaust gases from the combustion chamber, the number of air intake passages being greater than the number of the at least one exhaust passage, air intake valves arranged to selectively open and close the air intake passages, at least one exhaust valve arranged to open and close the at least one exhaust passage, an intake camshaft arranged to actuate the intake valves, an exhaust camshaft arranged to actuate the exhaust valve, both the intake and exhaust camshafts extending generally in parallel

to the center plane, and the intake camshaft lying closer to the center plane than the exhaust camshaft.

17. The internal combustion engine as set forth in Claim 16, wherein at least one of the air intake passages extend across the center plane.

5 18. The internal combustion engine as set forth in Claim 16, wherein the cylinder bore extends across the center plane.

19. The internal combustion engine as set forth in Claim 16, wherein both the intake and exhaust camshafts lie on the same side of the center plane within the hull.

MULTIPLE VALVE ENGINE FOR WATERCRAFT

ABSTRACT OF THE DISCLOSURE

A multiple valve engine for a watercraft includes an improved construction that contributes in balancing the weight of the engine between the port and starboard sides of the watercraft hull. The hull defines a center plane extending generally vertically from bow to stern. The engine includes a cylinder body defining at least one cylinder bore. An axis of the cylinder bore is inclined from the center plane. At least two intake passages communicate with a combustion chamber. Intake valves are arranged to selectively connect and disconnect the intake passages with the combustion chamber. At least one exhaust passage communicates with the combustion chamber. In one mode of the invention, the number of exhaust passages in the engine is less than the number of intake passages. At least one exhaust valve is arranged to selectively connect and disconnect the exhaust passage with the combustion chamber. The intake valves lie closer to the center plane than does the exhaust valve(s).

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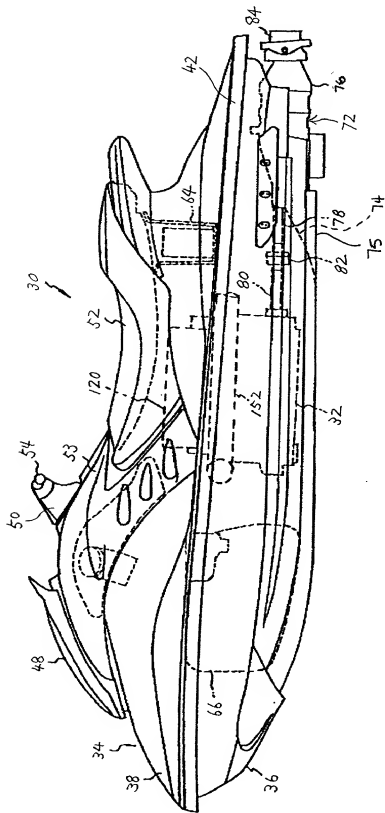


Figure 1

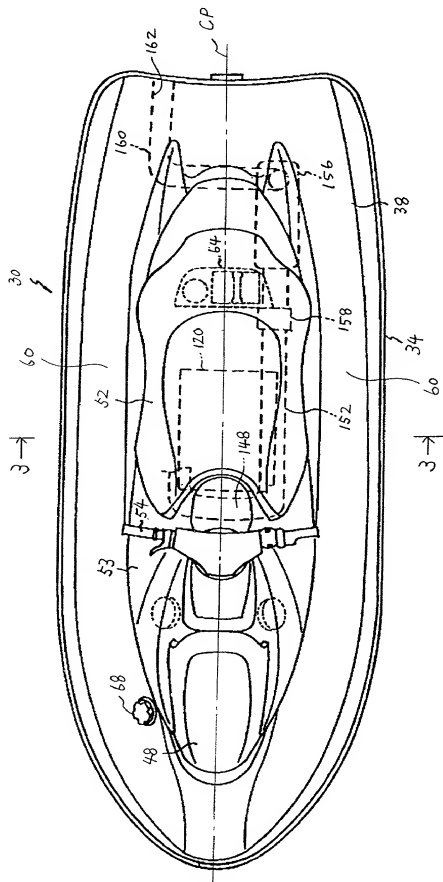


Figure 2

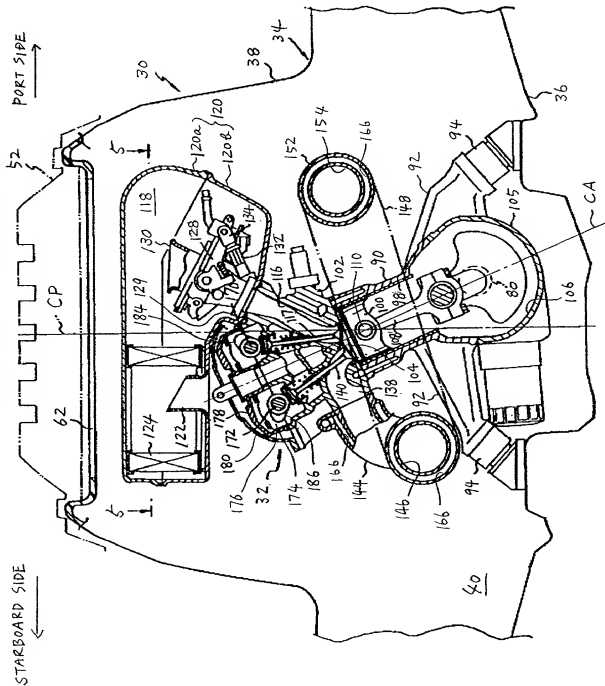


Figure 3

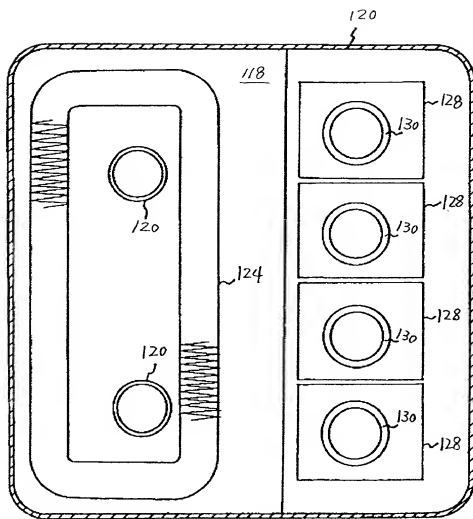


Figure 5

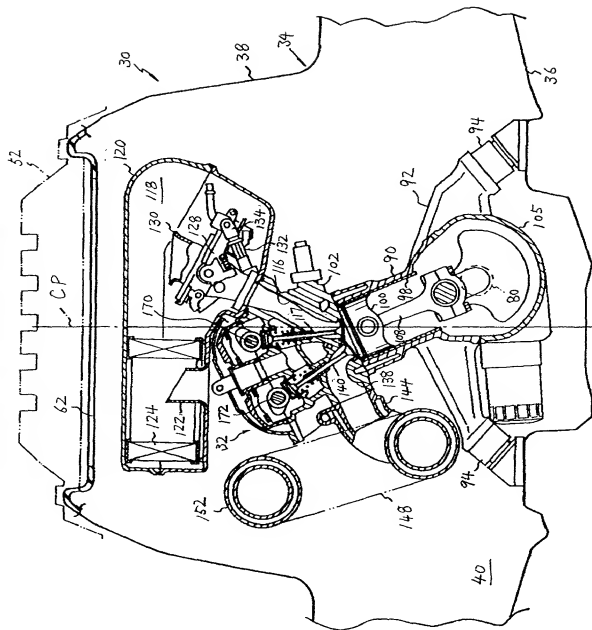


Figure 6